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Editorial

Ecosystem services – Bridging ecology, economy and social sciences

Human–environmental systems are challenged by current and upcoming ecological and socio-economic problems all over the world. Ecosystem degradation, resource depletion, social conflicts or economic up- and downturns are in everyone's consciousness. Human societies are complex adaptive systems but they are embedded within even more complex adaptive ecosystems. This requires integrative and innovative adaptive management approaches to meet environmental, social and economic demands of today's and future generations, and to find answers to an increasing number of questions posed to science. Giving this recognition, the concept of ecosystem services, which are provided to people by nature, has become increasingly popular since the 1990s, when the publications from de Groot (1992), Costanza et al. (1997) and Daily (1997) were launched. Due to the comprehensive consideration of the integration among various factors, this concept provides a valuable framework to define and analyze linkages and dependencies between natural and human systems. Therefore, it has been used as a framework for influential research initiatives, such as the Millennium Ecosystem Assessment (2001–2005; MA, 2005) which involved more than 1360 experts worldwide. But, the Millennium Assessment remained on a rather conceptual level and political application of outcomes is lacking so far. Hence, practical applications, appropriate methods for identification and quantification of individual services, suitable models, indicators and the integration of system components are still needed. The ongoing study on "The Economics of Ecosystems and Biodiversity" (TEEB, 2008) aims at analyzing the pathways from ecosystem structures and processes to human well-being. TEEB distinguishes three main types of ecosystem-based benefits and related values: (i) ecological benefits and values, (ii) socio-cultural benefits and values, and (iii) economic benefits and values. The integration of ecological, socio-cultural and economic benefits and value systems into holistic ecosystem services assessments is a challenge currently faced by a broad range of scientists, decision makers and practitioners.

This special issue of Ecological Complexity provides new insights and recent approaches in the fields of ecosystem services, bridging ecological, economic and social approaches. The ecosystem service concept is analyzed theoretically and potential applications in case studies are presented. The papers are the outcome of a long-lasting research cooperation (The Ecosystem Services Partnership[1]). They were presented during the international workshop on "Ecosystem Services – Solution for Problems or a Problem that needs Solution" held in May 2008 in Salzau,[2] northern Germany. With regard to scientific and practical applications of the ecosystem service concept, the following key topics were discussed during this workshop. The questions below the topics were indicated by the participants to be most relevant for future ecosystem service research:

A. New concepts and methods to describe, model and quantify ecosystem services on different and multiple spatial and temporal scales:
   - How can environmental structures and functions be translated into ecosystem services?
   - How can we indicate services that are hardly transferable into economic accounting systems?
   - How can we apply ecosystem principles to landscapes?
   - Are there scale-invariant components in the service approach?
   - How do different ecosystem services interact?
   - Is it sufficient to assess some selected services or is it necessary to take all significant services into account in an assessment study?

B. Bridging existing concepts: multifunctionality – ecosystem services – environmental accounting:
   - Which are the relations between ecosystem services and ecosystem integrity and ecosystem health?
   - Which role can ecosystem services play to represent sustainable development?
   - Which are the relationships and differences between ecosystem services, landscape multifunctionality and land use functions?

C. Potentials and limits of economic quantifications:
   - Is the utilitarian evaluation approach really suitable and sufficient for environmental decision making?
   - Is an economic valuation necessary in all cases or are there scientific alternatives?
   - Which are the limitations of monetary service valuation?
   - Are the results of different economic valuation methods (e.g. hedonic pricing, travel cost, willingness to pay, replacement costs) really compatible?
   - How can different items of valuation be combined?
   - Which are the factual interactions between ecosystem services and human well-being and how do they differ in different regions?

D. The distinctive role of supporting services, ecological integrity and biodiversity:
   - Which is the role of biodiversity with reference to ecosystem services?
   - Is it sufficient to reduce biodiversity to a cultural service or a supporting function?

[1] http://www.es-partnership.org/.
[2] http://www.uni-kiel.de/ecology/users/fmueller/salzau2008/.

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E. Government support and application of the ecosystem services concept:
  - How can the service approach be transferred into environmental management?
  - How can ecosystem services be used as scenario components?
  - How can ecosystem services optimally be used in decision making processes?

F. Cooperation among scientists:
  - How can we improve international cooperation and networking?
  - How can we cope with the necessary high degree of interdisciplinarity?

The above mentioned topics and questions are reflected by the papers in this Special Issue. Since the concept of ecosystem services requires an integrated approach, it is important to highlight that the papers published in this Special issue are often related to more than one single topic.

Most of the contributions are dedicated to *new concepts and methods* for ecosystem service assessment. De Groot et al. (2010) provide an overview of the state-of-the-art of ecosystem service research and present a comprehensive list of services, relevant process, state and performance indicators. Assessments based on GIS modeling on regional scales are presented by Klug and Jenewein (2010), Pert et al. (2010) and Vihervaara et al. (2010). Ecological modeling as a tool for ecosystem service assessment is applied by Patten (2010); developing network models) and Trepel (2010); modeling peatland water and matter budgets). Vegetation types and their condition are used as a surrogate to map underlying ecosystem services by Yapp et al. (2010). The concept of Ecosystem Service Providers (ESPs) at multiple spatial scales and the implication for environmental planning and management are presented by Petrosillo et al. (2010). In this paper, the authors put in relation the idea of ESPs to the concepts of disturbance and vulnerability and are thereby moving to the next topic focused on *bridging existing concepts*. The framework for the quantification of ecosystem services provided by the Millennium Ecosystem Assessment is applied by Pinto et al. (2010) in a Portuguese catchment area. Paetzold et al. (2010) introduce the use of Ecosystem Service Profiles (called ESPs as well) in order to evaluate ecological quality.

The use and methods of *economic ecosystem services quantification* are heatedly debated in Spangenberg and Settele (2010). They argue, that economic valuations go beyond their actual target, which should be the protection of the environment and biodiversity. Nevertheless, de Groot et al. (2010) provide a valuable overview of economic and non-economic techniques available to value biodiversity. Jørgensen (2010) suggests an estimation of the value of services provided by ecosystems by linking eco-exergy indicators to concrete monetary units for work capacities. Multiple ecosystem services in a tropical forest landscape are evaluated and different land use options are compared by Olschewski et al. (2010). Three selected agricultural supporting ecosystem services and their economic values under organic and conventional farming regimes are quantified by Sandhu et al. (2010). Klug and Jenewein (2010), Pinto et al. (2010) and Trepel (2010) calculate the costs of alternative landscape management measures based on the results of their analyszes. Klug and Jenewein (2010) suggest the use of "spatial econometrics" – spatially explicit units attributed with economic units. The share of tangible versus *intangible ecosystem services* in local decision making is analyszed by Vejre et al. (2010). They find out, that intangible (or "soft") ecosystem services can hold a higher value than tangible ("hard") ecosystem services. The high value of intangible ecosystem services is also explored by Gee and Burkhard (2010), concentrating their analysis on non-use respective intrinsic values of a coastal region in relation to installations of offshore wind farms.

To understand *the role of supporting ecosystem services* and ecosystem functions, the links between ecosystem properties and ecosystem services have to be understood (de Groot et al., 2010) and more knowledge on ecosystem functioning has to be generated (Patten, 2010). The main driver of anthropogenic ecosystem changes are the impacts caused by land use change. Such impacts of land use change are described by Petrosillo et al. (2010), Vihervaara et al. (2010), Olschewski et al. (2010), Klug and Jenewein (2010) and Pert et al. (2010). Impacts of climate change on biomass production and biodiversity in a local reed ecosystem is the background of the study by Dolinar et al. (2010). Patten's network models (Patten, 2010) compare natural ecosystem properties to ecosystems under human use and their changing capacities to provide services. The role of soil formation, mineralization of plant nutrients and biological pest control in agriculture are assessed by Sandhu et al. (2010). With regard to the concept of supporting ecosystem services (MA, 2005), several authors suggest to treat them differently from the other ecosystem services which provide their benefits directly to humans. Moreover, due to some thematic overlaps with regulating ecosystem services, there is a high risk of double-counting particular natural processes. De Groot et al. (2010) suggest to call this group "habitat or supporting services" consisting of "nursery habitat" and "genepool protection" and Paetzold et al. (2010) assessed ecological integrity respective to ecological quality based on ecosystem services. In other terms, they highlight the link between ecological integrity and ecosystem services from the other end of the supply chain. Interestingly, there is no paper in this Special Issue directly addressing *the role of biodiversity* for the provision of ecosystem services. However, it is expected from the outcomes of TEEB (2008) to deliver further insights into this particular topic.

The transfer of the ecosystem services approach into environmental management and its *government support* is the second topic not sufficiently addressed so far. However, the impacts of existing policy schemes on the provision of ecosystem services is addressed by Klug and Jenewein (2010); for European Common Agricultural Policy), Trepel (2010); derived a decision support system for the European Water Framework Directive) and Pert et al. (2010); for the regional Tully Water Quality Improvement Plan under the Australian Reef Water Quality Protection Plan). Exemplary environmental management recommendations were given by Yapp et al. (2010), suggesting the use of maps of vegetation condition and structure. Patten (2010) recommends a management of ecosystem networks near a steady state, where the demand of ecosystem services for human well-being and their supply by nature would interact in a negative feedback loop, leading to stable conditions. Vihervaara et al. (2010) suggest to support decision makers with information in a form that is understandable, even for non-experts and if concrete data is lacking. This obvious deficit was taken up by the Ecosystem Services Partnership and the meeting in Salzau in 2010[3] aims at providing "Solutions for Sustaining Natural Capital and Ecosystem Services". The *cooperation among scientists* and the challenge to cope with interdisciplinarity are still characterized by immaturity and a lot of effort is needed. With regard to ecosystem services, the creation of the Ecosystem Services Partnership on the Conference on Modelling Ecosystem Services in 2009[4] in Lecce/Italy has been one step forward towards improvements in cooperation and exchange of knowledge.

[3] http://www.uni-kiel.de/ecology/projects/salzau/.
[4] http://www.mes2009.it.

After reading the papers in this Special Issue, *future research needs* become apparent: in the beginning, there seems to be a clear need of a consistent terminology, applicable by scientists with interdisciplinary backgrounds as well as understandable to decision makers (de Groot et al., 2010, Vejre et al., 2010; Paetzold et al., 2010). What, for example, is the background of supporting ecosystem services versus ecological integrity versus habitat services versus ecosystem functions and benefits? Is an additional distinction in green, blue and yellow services, as suggested by Klug and Jenewein (2010), convenient? One important tool are ''master lists'' of relevant ecosystem services as suggested by de Groot et al. (2010) and applied by Vihervaara et al. (2010). In combination with appropriate tools and indicators, date suitable for the quantification of individual ecosystem services in such a list have to be acquired. So far, most studies incorporate a comprehensive conceptual framework for ecosystem service assessment but in most cases actual quantifications are carried out for selected services on selected scales only. When it comes to spatial scales, the case studies presented in this Special Issue show a clear dominance of local scale studies (Sandhu et al., 2010; Dolinar et al., 2010; Vejre et al., 2010; Pinto et al., 2010) and studies referring to regional/landscape scales (Pert et al., 2010; Gee and Burkhard, 2010; Klug and Jenewein, 2010; Vihervaara et al., 2010; Petrosillo et al., 2010; Trepel, 2010; Olschewski et al., 2010). Global aspects are included only in de Groot et al. (2010). One way to address future dynamics by manipulating temporal scales can be scenarios (e.g. in Klug and Jenewein, 2010; Trepel, 2010; Olschewski et al., 2010).

In order to make the information suitable for resource management, supply and demand sides of ecosystem services have to be surveyed, including desires of stakeholders, residents and their respective ''level of satisfaction'' (Klug and Jenewein, 2010) and long-term effects (Paetzold et al., 2010). On the other hand, an important function of managing complex systems should be to inform decision-makers about when and where an undesirable state change, which can diminish or enhance the provision of ecosystem services, is likely to occur. By mapping ecosystem services supply and demand, import and export flows of goods and services can be quantified. If the demand of goods and services exceeds the supply in a region, a self-sustaining maintenance is not given and an ''Ecosystem Services Footprint'' will be left somewhere else. Up to now, the demand for tools and data to carry out quantifications in ecological, economic as well as social aspects of ecosystem services exceeds the supply of appropriate material. Therefore, schemes for monitoring ecosystem services should be installed accordingly, covering different spatial and temporal scales. There is still a lot more experience and knowledge in the form of applications, methods, models, data and communication needed but it is good to know, that they are under way, as this special issue might indicate.

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